Appendix V5-6A

Hope Bay Belt Project, Metal Concentrations in Fish Tissues from Five Lakes in the Hope Bay Belt, Nunavut

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BHP DIAMONDS INC.
HOPE BAY BELT PROJECT

METAL CONCENTRATIONS IN FISH TISSUES FROM FIVE LAKES IN THE HOPE BAY BELT, NUNAVUT

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1. Introduction

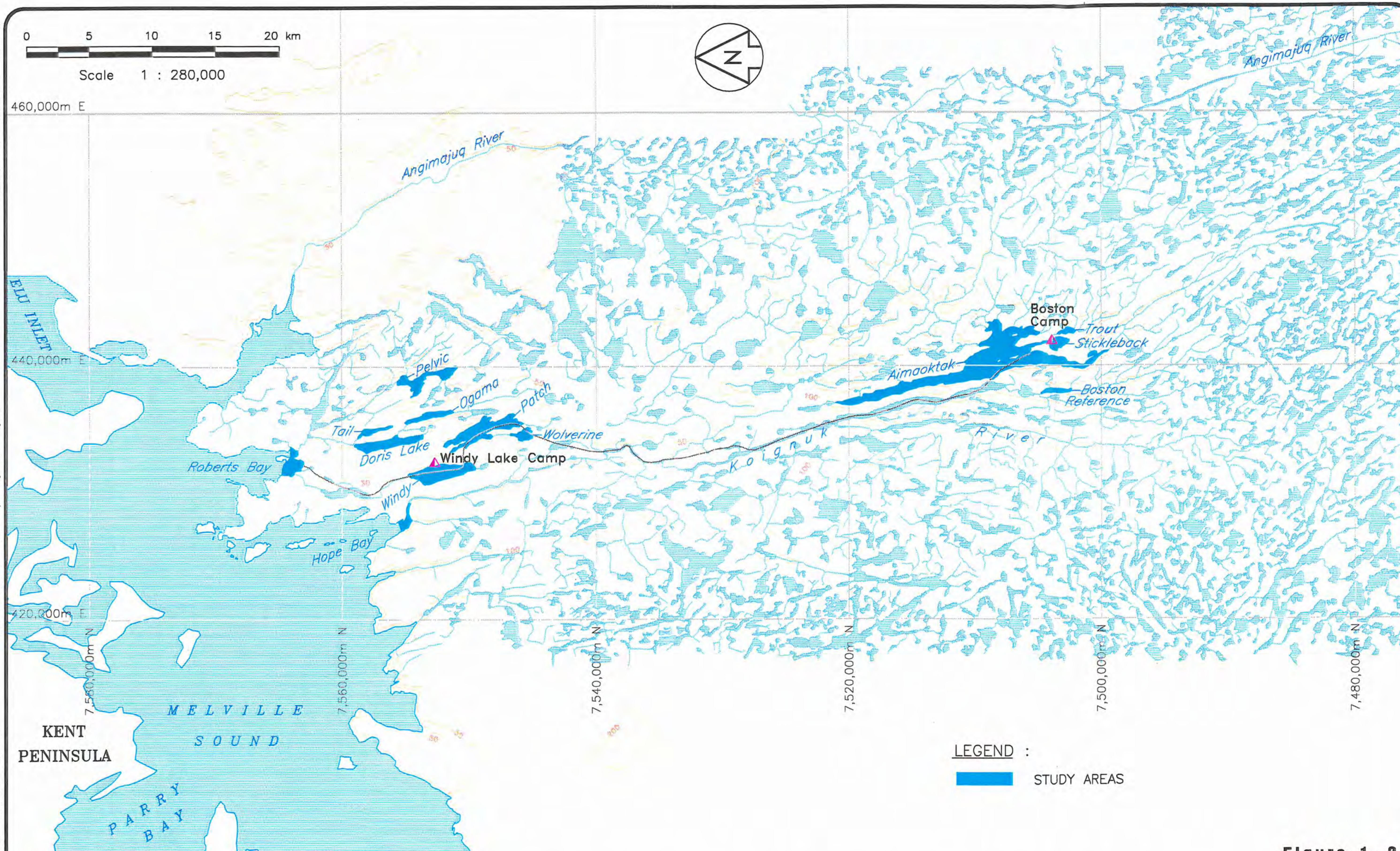
1. INTRODUCTION

In May 1998, BHP Minerals of Canada Inc. amalgamated with BHP Diamonds Inc., and assumed ownership of the Hope Bay Belt Project. The Project includes the Boston, Doris Lake, and Madrid properties, the proposed Roberts Bay port site, Hope Bay, and a winter road corridor connect these areas. These properties are located 50 km east of Omingmaktok, Nunavut (Figure 1-1). Until the amalgamation, BHP Minerals had managed the environmental baseline study. The intent of this program is to generate a comprehensive database of biophysical, socioeconomic, heritage, and cultural information needed for exploration and future development approvals.

As a component of the baseline fisheries program, dorsal myomere (muscle) and livers were collected from lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*; where present) from selected lakes. These lakes were selected for their proximity to potential development activities. Tissues were collected from fishes from Doris, Patch, and Windy at the Doris Lake Property and Aimaoktak (Spyder) Lake at the Boston Property in 1997 (Figure 1-2). In 1998, tissues were collected from fishes from Patch Lake (selected as a regional reference lake; Figure 1-2). The Aimaoktak Lake samples were processed in 1997 and the remaining tissues were held in storage for analysis in 1998.

In 1998, the environmental baseline program was reduced to match a decrease in exploration activity as BHP's operations moved from active exploration to a care and maintenance phase. Because of these changing circumstances, the analyses of the previously collected tissue samples were initially deferred indefinitely. However, to obtain meaningful results from the frozen tissue samples, analyses should be conducted within two years of sample collection (Mr. Fred Chen, Senior Analyst, Analytical Services Laboratories, *pers. comm.*). Storage beyond two years would likely lead to sample degradation and thus inaccurate results.

The lakes of the Hope Bay Belt are ultra-oligotrophic (Rescan 1998). As such, the productivity of the fish communities is relatively low. These communities are characterized by long-lived, slow-growing fishes (Rescan 1998; 1999). Therefore, Cad No. C1081 Sht. 16 View L1 Job No. 526-9 1998 Hope Bay Belt Project 03/26/1999- 9:25am RES_BL



BHP

Figure 1-2

Locations of Study Lakes and Marine Areas, Hope Bay Belt

Rescan

the fish communities are sensitive to disturbances, such as fishing. The Hope Bay Belt continues to be a promising resource for future development. As part of the environmental assessment that will be required, baseline tissue metals data will be needed. Therefore if the samples were allowed to degrade, new samples would need to be collected. As the fish communities have already been characterized, collecting additional tissue samples would be costly and the removal of additional fishes would be deleterious to the resident fish communities.

The Department of Fisheries and Oceans (DFO), Iqaluit, recognized that the tissues held in storage represented a valuable source of baseline information for fish communities in the northern Slave Geological Province of Nunavut.

As a result, a cooperative effort was undertaken between BHP and DFO whereby both parties shared the costs and results of the tissue analyses. DFO contributed funding to complete the tissue analysis. BHP contributed funding for the data analysis and reporting, in addition to expenses already incurred for the collection and processing of the tissues.

Rescan™ Environmental Services Ltd. was contracted to facilitate the analysis of the tissues and resultant data and to generate the following report. Contained in this report are the results of the tissue analyses for Doris, Patch, Pelvic, and Windy lakes. In addition, the results for Aimoaktak Lake (analyzed in 1997) are also presented.

2. Methods

2. METHODS

Tissue samples were collected from fishes of four Doris Property lakes (Doris, Patch, Pelvic, and Windy) and one Boston Property lake (Aimoaktak). All fishes were captured during the lake survey programs of 1997 and 1998 using index gill nets.

2.1 Fish Collection

Index gill net gangs consisted of three panels of 3.8 cm (1.5") mesh. Each panel measured 15.0 m long by 2.44 m deep for an area of 36.6 m^2 and a total area of 109.8 m^2 per gang. Index gangs were deployed in what are termed "rounds". During a round, three to four index gangs were set in succession and soaked for 60 minutes. The gangs were then retrieved in order of setting and the captured fishes were sampled. Once the fishes were sampled, the gangs were re-deployed for another round. All surveys were evening surveys: conducted between 2000 hr and midnight.

An Arctic Lake Trout Index Gillnetting (ALTIG) program was designed and first implemented at the BHP Ekati Mine site in 1994 (McCarthy 1997). The basis for the program was an Ontario Ministry of Natural Resources Fisheries Assessment Unit index gillnetting design developed to assess the abundance of lake trout in Ontario lakes (Willox and Lester 1994). A trial ALTIG program concluded that single mesh size nets (3.8 cm) provided essentially the same data as the three mesh sizes used in Ontario but with fewer fish mortalities (3.8, 5.1, 6.4 cm; McCarthy 1997).

Though there are other survey methods available to sample fish communities, gill nets provide a highly effective means of sampling large numbers of fishes. When used in an ALTIG program, they provide a standardized methodology that generates quantitative data. Other methods such as trap nets and beach seines are dependent on shoreline gradient and substrate type for positioning. Hence, sampling opportunities are reduced, if even possible. Gill nets are independent of these factors and can be used for waterbodies that are inaccessible to trap nets and beach seines. Incidental mortalities, the greatest concern with gill nets, are minimized by restricting the soaking time to no greater than 60 minutes (McCarthy 1997).

All captured fishes were identified to species, measured for fork length (mm), weighed (gm), sampled for aging structures, and released. Left pectoral fins were used for aging structures. In addition, all fishes over 300 mm were marked with a uniquely numbered Floy anchor tag. For mortalities, sex, maturity, and reproductive status were recorded, and otoliths and stomachs were removed for aging and content analysis, respectively.

2.2 Tissue Collection

Dorsal myomere (muscle) samples and livers were collected opportunistically from lake trout (*Salvelinus namaycush*), and lake whitefish (*Coregonus clupeaformis*) mortalities. Samples were collected following the procedures outlined in the British Columbia Field Sampling Manual (MELP 1996). A minimum of 100 gm of myomere tissue was collected from each fish, as well as the complete liver, minus the bile gland. Samples were individually stored in labeled, clean plastic Whirl-Pac bags until analysis. Analyses were conducted by Analytical Services Laboratories Ltd. (Vancouver, British Columbia). Trace metals and the methods used for analyses are listed in Table 2-1. For each species and tissue type in each lake, results were combined and presented as a mean.

2.3 Data Analysis

Mean tissue concentrations for 19 trace metals were calculated. For results that were less than the detection limit, values of one half the detection limit were employed when calculating mean concentrations of trace metals in tissues. This method was used by Swyripa *et al.* (1993) and Harbicht and Ash (1991) for fish tissues from Trout Lake, Northwest Territories and Contwoyto Lake, Nunavut, respectively.

Tissue mercury concentrations were regressed against age and fork length of fishes. Mercury concentrations were presented on the dependent axis (Y) and the age or fork length of the fish on the independent axis (X). For lake whitefish, the age and fork length were transformed into logarithmic values. This was found to result in a more significant relationship. A basic linear regression was performed and the regression line equations and R^2-values calculated.

Table 2-1
Detection Limits and Methods for Determining Metal Concentrations in Fish Tissue

Element	Detection Limit[1] (mg/kg, wet weight)	Method[2]
Aluminum	5	ICP
Arsenic	0.05	HVAAS
Barium	0.5	ICP
Beryllium	0.2	ICP
Cadmium	0.02	ICP
Calcium	10	ICP
Chromium	0.5	ICP
Cobalt	0.5	ICP
Copper	0.5	ICP
Iron	1	ICP
Lead	0.05	GFAAS
Magnesium	0.05	ICP
Manganese	0.2	ICP
Mercury	0.005	CVAAS
Molybdenum	1	ICP
Nickel	1	ICP
Selenium	0.1	HVAAS
Silver	0.1	ICP
Zinc	0.3	ICP

1: All detection limits are based on a minimum of 15 grams (dry weight) of sample
2: CVAAS = Cold Vapor Atomic Absorption Spectrophotometry
GFAAS = Graphite Furnace Atomic Absorption Spectrophotometry
HVAAS = Hydride Vapor Atomic Absorption Spectrophotometry
ICP = Inductively Coupled Argon Plasma/Atomic Emission Spectrophotometry

3. Results and Discussion

3. RESULTS AND DISCUSSION

Tissue samples were collected from fishes captured during the Hope Bay Belt environmental baseline fisheries surveys (Rescan 1998, 1999). These surveys were conducted in August, 1997, and August, 1998. The following sections present the results and brief discussions of the tissue analyses for trace metals concentrations in fish tissues from selected Hope Bay Belt lakes.

3.1 Fish Sampling

A total of 219 fishes (118 lake trout and 101 lake whitefish) from Aimaoktak, Doris, Patch, Pelvic, and Windy lakes were sampled for tissues (Table 3-1). Fishes were harvested from Aimaoktak, Doris, Patch, and Windy lakes in August, 1997, and from Pelvic Lake in August, 1998. The tissues from Aimaoktak Lake were analyzed and reported in 1997 (Rescan 1998). The remaining tissues were analyzed in February, 1999. The data codes and raw data are presented in appendices 3-1 to 3-6.

Table 3-1
Number of Fishes and Tissues Sampled per Species from Hope Bay Belt Lakes, 1997 and 1998

	Species				
	LKTR		LKWH		
Lake	**Myomere**	**Liver**	**Myomere**	**Liver**	**TOTAL**
Doris	22	22	29	29	102
Patch	25	25	26	26	102
Windy	25	25	None Present		50
Aimaoktak	25	25	24	24	98
Pelvic	21	21	22	22	86
TOTAL	**118**	**118**	**101**	**101**	**438**

Where possible, young adult fishes were sampled. Large adult fishes, especially lake trout, were released. This is because large lake trout impose a significant degree of control on the fish community dynamics in lakes (Welch and Klings 1996). The removal of large, older lake trout typically results in a destabilization of the lake fish community and subsequently requires a number of years to restabilize.

3.2 Trace Metals

The mean tissue concentrations of 19 trace metals were calculated. These results are presented in Tables 3-2 to 3-6. Although analyses provide results for all 19 trace metals, brief discussions of four key trace metals (arsenic, cadmium, copper, and lead) are presented below, followed by a more detailed discussion of mercury.

3.2.1 Arsenic

Arsenic is a cumulative toxin, bioaccumulating in fish tissues such as liver and myomere (Falk *et al.*, 1973). Dressed myomere tissue concentrations for human consumption have been set by the Canadian Food and Drug Directorate (CFDD) at 5 ppm. The highest arsenic concentrations were found in Windy Lake lake trout (Table 3-4). The mean myomere tissue concentration (0.82±0.037 ppm) was well below the guideline limit of 5 ppm. The mean liver tissue concentration (4.20±0.351 ppm) was also below the guideline limit.

3.2.2 Cadmium

Cadmium is known to accumulate in gill, kidney, liver, and, to a lesser extent, myomere tissues (Sprague, 1987). Cadmium is also known to occur in higher concentrations in fishes of the lower trophic levels (Windom *et al.*, 1973). These conditions held true for the Hope Bay Belt tissues. Cadmium was not detectable in myomere tissue of either lake trout or lake whitefish (Tables 3-2 to 3-6). However, it was detected in liver tissues and was found to be at higher concentrations in whitefish. The highest mean concentration of Cadmium was found in Pelvic Lake whitefish (0.88±0.110 ppm; Table 3-6).

3.2.3 Copper

Copper is a biologically essential trace metal that at high concentrations is toxic (Forstner and Wittman, 1979). However, copper does not bioaccumulate as most of it is excreted (Falk *et al.*, 1973). The CFDD guideline for dressed myomere tissue is 100 ppm (Falk *et al.*, 1973). Copper was not detectable in myomere tissue of either lake trout or lake whitefish (Tables 3-2 to 3-6). However, copper was present in livers of both species. The highest mean concentration was in Windy Lake trout (222±22.9 ppm). The higher concentrations of copper in livers is not unexpected. Copper is an essential constituent in metalloenzymes (Demayo *et al.*, 1982).

3.2.4 Lead

Lead is known to bioaccumulate in the bones, scales, kidney, and liver of fishes (Spry and Wiener, 1991). However, it neither biomagnifies nor does it increase with size and age. CFDD guidelines for dressed fish myomere is 10 ppm. Lead was not found in any of the myomere samples from lake trout or lake whitefish (Tables 3-2 to 3-6). Lead was only detected in a portion of the liver samples from Pelvic Lake whitefish (Table 3-6). The mean concentration of lead was found to be 0.58±0.054 ppm.

Table 3-2
Mean Concentrations of Metals (ppm) in Lake Trout and Lake Whitefish Tissues from Doris Lake, 1997

		Lake Trout				Lake Whitefish			
Tissue		Myomere		Liver		Myomere		Liver	
Number		Mean	se	Mean	se	Mean	se	Mean	se
Length (mm)		637	29.0			446	7.1		
Weight (g)		2772	404.9			1224	68.2		
Age (yr)		30	2.7			29	2.8		
Moisture	%	80.0	0.38	78.7	0.55	79.9	0.32	80.1	0.32
Aluminum	T-Al	<5		3.48	0.562	<5		4.11	0.585
Arsenic	T-As	0.057	0.0061	0.039	0.0049	<0.05		0.075	0.0093
Barium	T-Ba	<5		<5		<5		<5	
Beryllium	T-Be	<0.2		<0.2		<0.2		<0.2	
Cadmium	T-Cd	<0.02		0.020	0.0023	<0.02		0.039	0.0040
Calcium	T-Ca	127.3	14.98	63.2	2.86	155.9	10.49	107.8	25.62
Chromium	T-Cr	<0.5		<0.5		<0.5		<0.5	
Cobalt	T-Co	<0.5		<0.5		<0.5		<0.5	
Copper	T-Cu	<0.5		13.1	1.22	<0.5		3.90	0.338
Iron	T-Fe	2.32	0.138	217.7	29.06	2.68	0.133	128.2	11.12
Lead	T-Pb	<0.05		<0.05		<0.05		<0.05	
Magnesium	T-Mg	235.9	4.69	131.0	3.98	240.9	3.51	144.3	3.29
Manganese	T-Mn	0.105	0.0046	1.23	0.054	0.136	0.0108	1.89	0.073
Mercury	T-Hg	0.28	0.029	0.51	0.064	0.066	0.0059	0.168	0.0178
Molybdenum	T-Mo	<1		<1		<1		<1	
Nickel	T-Ni	<1		<1		<1		<1	
Selenium	T-Se	0.20	0.005	1.10	0.061	0.195	0.0017	1.03	0.012
Silver	T-Ag	<0.1		0.100	0.0100	<0.1		<0.1	
Zinc	T-Zn	2.88	0.045	29.2	0.97	2.60	0.012	21.0	0.13

Table 3-3
Mean Concentrations of Metals (ppm) in Lake Trout and Lake Whitefish Tissues from Patch Lake, 1997

		Lake Trout				Lake Whitefish			
Tissue		**Myomere**		**Liver**		**Myomere**		**Liver**	
Number		**Mean**	**se**	**Mean**	**se**	**Mean**	**se**	**Mean**	**se**
Length (mm)		625	25.5			425	5.7		
Weight (g)		2524	288.4			1012	46.9		
Age (yr)		23	1.4			24	1.4		
Moisture	%	79.1	0.36	79.0	0.45	79.5	0.23	76.9	0.66
Aluminum	T-Al	<5		8.04	2.167	<5		7.15	0.686
Arsenic	T-As	0.080	0.0082	0.112	0.0173	0.070	0.0058	0.258	0.0288
Barium	T-Ba	<0.5		<0.5		<0.5		<0.5	
Beryllium	T-Be	<0.2		<0.2		<0.2		<0.2	
Cadmium	T-Cd	<0.02		0.030	0.0049	<0.02		0.064	0.0076
Calcium	T-Ca	154.0	13.43	64.8	3.56	181.3	11.30	94.5	16.18
Chromium	T-Cr	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	
Cobalt	T-Co	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	
Copper	T-Cu	<0.5		12.6	1.46	<0.5		4.6	0.52
Iron	T-Fe	2.60	0.163	348.1	61.87	2.52	0.033	131.7	3.51
Lead	T-Pb	<0.05		<0.05		<0.05		<0.05	
Magnesium	T-Mg	252.0	3.97	119.8	5.15	263.1	2.73	149.2	2.77
Manganese	T-Mn	<0.2		1.21	0.072	<0.2		1.70	0.063
Mercury	T-Hg	0.392	0.0331	0.692	0.0743	0.120	0.0112	0.393	0.0380
Molybdenum	T-Mo	<1		<1		<1		<1	
Nickel	T-Ni	<1		<1		<1		<1	
Selenium	T-Se	0.220	0.0082	1.642	0.1238	0.215	0.0072	1.627	0.0643
Silver	T-Ag	<0.1		<0.1		<0.1		<0.1	
Zinc	T-Zn	2.62	0.048	28.42	1.471	2.49	0.041	27.13	0.792

Table 3-4
Mean Concentrations of Metals (ppm) in Lake Trout Tissues from Windy Lake, 1997

		Lake Trout			
Tissue		Myomere		Liver	
Number		Mean	se	Mean	se
Length (mm)		434	4.4		
Weight (g)		845	24.1		
Age (yr)		18	1.2		
Moisture	%	79.3	0.30	78.8	0.57
Aluminum	T-Al	<5		15.6	2.29
Arsenic	T-As	0.082	0.0037	0.420	0.0351
Barium	T-Ba	<0.5		<0.5	
Beryllium	T-Be	<0.2		<0.2	
Cadmium	T-Cd	<0.02		<0.02	
Calcium	T-Ca	120.0	9.04	58.1	1.91
Chromium	T-Cr	<0.5		<0.5	
Cobalt	T-Co	<0.5		<0.5	
Copper	T-Cu	<0.5		22.2	2.29
Iron	T-Fe	3.8	0.28	370.9	52.8
Lead	T-Pb	<0.05		<0.05	
Magnesium	T-Mg	267.4	3.34	142.7	4.19
Manganese	T-Mn	<0.2		1.09	0.058
Mercury	T-Hg	0.036	0.0030	0.056	0.0062
Molybdenum	T-Mo	<1		<1	
Nickel	T-Ni	<1		<1	
Selenium	T-Se	0.488	0.0088	1.960	0.1254
Silver	T-Ag	<0.1		0.032	0.0138
Zinc	T-Zn	2.65	0.031	34.18	1.305